Mini-Review

iMedPub Journals
http://www.imedpub.com

Archives of Clinical Microbiology
ISSN 1989-8436

2021
Vol. 12 No. 6:180

Natural Emergence and Severity of Leaf and Glume Blotch Diseases of Winter Wheat and Winter Triticale Incited by Complex of Fungi *Parastagonospora* spp./*Zymoseptoria tritici* under Climatic Conditions of Poland

Edward Arseniuk *

Department of Plant Breeding and Acclimatization, Institute-National Research Institute, Blonie, Poland

***Corresponding author:** Arseniuk E,

Plant Breeding and Acclimatization, Institute-National Research Institute, Blonie, Poland, India

e.arseniuk@ihar.edu.pl

Citation: Arseniuk E (2021) Natural Emergence and Severity of Leaf and Glume Blotch Diseases of Winter Wheat and Winter Triticale Incited by Complex of Fungi *Parastagonospora* spp./ *Zymoseptoria tritici* under climatic conditions of Poland. Arch Clin Microbiol Vol.12 No.S5: 180.

Abstract

The overall purpose of the presented minireview is to show natural emergence of very destructive necrotrophic fungi from genera of *Parastagonospora* spp. and *Zymoseptoria tritici* known to infect grasses and cereal crops including winter wheat and winter triticale worldwide. The study of natural emergence of the fungal species was conducted in 8 different geographic locations of Poland. The experiments were done with 10 winter wheat and 10 winter triticale varieties planted to field plots of 10 m^2 in a randomised block design. In spring and early summer plants on the plots were assessed visually om emergence of diseases caused by the pathogens and diseased plant parts from each plot were collected for microscope inspection. The reason of the inspection was to determine by which pathogen plants were affected and how the dieseases progressed upwards on the cereal plants. Significant differences among the eight locations spread around the country were found. *Zymoseptoria tritici* was most frequently identified on the studied genotypes of winter wheat. On the other hand the most frequently isolated pathogen from different heights of winter triticale plants was *P. nodorum*. The incidence of *P. avenae* f. sp. *triticea* on both crops, wheat and triticale appeared to be much less frequently isolated from infected plant parts at different heights than that of *Z. tritici* and *P. nodorum*. The present research also aimed to prove statistically the impact of climatic factors on the natural emergence of the pathogens affecting green plant parts at various plant heights of winter wheat and winter triticale in Poland. However, the plant-pathogen-climate interactions were not proven statistically. The bunch of correlation coefficients, sometimes positive, sometimes negative were very low, thus making inferences about disease emergence at different plant heights appeared to be quite risky.

Keywords: Winter wheat; Winter triticale; Natural leaf and glume blotch incidence; *Parastagonospora* spp., *Zymoseptoria tritici*

Introduction

Complex of necrotrophic fungi from genera of *Parastagonospora* spp./*Zymoseptoria tritici* has been observed to occur naturally on cereal and grass species for quite a number of years. The occurrence of *P. nodorum*, *Z. tritici*, and *P. avenae* f.sp. *triticea* depends not only on cereal species but also on multiple climatic factors [1-14]. Symptoms and severity of diseases evoked by the above pathogens appear to be of different magnitude depending upon course of weather conditions to which belong: frequent rainfalls, high relative air humidity and air temperatures about 20-25°C. The latter conditions are very conducive for development of blotches incited by *Parastagonospora* spp. and especially by *P. nodorum*, *Zymoseptoria tritici* and *P. avenaria* f.sp. *triticea*.

The above pathogens are considered the most devastating for the small-grain cereals and especially for wheat (*Triticum aestivum* L.) and triticale (× *Triticosecale* Wittm.) [3, 15-20]. Diseases incited by *Parastagonospora* spp. and *Zymoseptoria tritici* cause significant quantitative and qualitative grain yield losses and hamper grain production of the above indicated small grain cereal species.

According to a number of reports the pathogens from the *Parastagonospora* spp/ *Zymoseptoria tritici* complex afflict cereal species with substantial grain yield losses in quantity and quality. Parastagonospora nodorum blotch (syn. Stagonospora nodorum blotch, SNB) may cause grain yield losses in wheat of up to 31% [15]. On the other hand Zymoseptoria tritici blotch (syn. Septoria tritici blotch, STB) may reduce grain yield losses in wheat as much as 50% [20]. It should be mentioned, that Zymoseptoria tritici blotch did not occur on triticale at all, however, in recent years appeared reports claiming that the latter disease occurs also on triticale, which hectarage in Poland reached 1,3 millions ha. Along with increased triticale popularity, the crop is being affected by a number of new, mainly of wheat origin diseases.

It is to underline that the above reported losses afflicted by necrotrophic pathogens *Parastagonospora* spp./*Zymoseptoria tritici* adversely affect primarily wheat production in Poland and other European countries [21,22]. On the other hand some time ago Arseniuk et al. [15] reported a negative impact of *Parastagonospora* spp./*Z. tritici* complex on the quality and quantity of wheat and triticale grain, which is shriveled and of reduced size. Since then the situation got aggravated. New pathogens and diseases appeared on triticale in the last decades.

It also should be indicated that another fungal pathogen from *Parastagonospora*/*Zymoseptoria* complex, namely *P. avenae* f. sp. *triticea*, is considered as a minor pathogen of wheat [10,23,24] and triticale [1]. Two special forms of *P. avenae* were identified. From our study results, that the first one, the *P. avenae* f. sp. *triticea* (NCBI:txid54790: *Parastagonospora avenae* f. sp. *tritici*) may severely affect wheat and triticale. The second one, the *P. avenae* f. sp. *avenaria* (NCBI:txid215456: *Parastagonospora avenae* f. sp. *avenae*), is destructive to oats [14]. In later studies, McDonald et al. [25], determined genetic differences in groups of isolates of *Phaeosphaeria* spp., and 5 phylogenetically distinct clades were identified: Pat1, Pat3, Pat4, Pat5, and Pat6. In Poland, *P. avenaria* f.sp. *triticea* isolates Pat2 and some homothallic *P. avenaria* f.sp. *triticea* isolates Pat1 occurred on foxtail barley (*Hordeum jubatum*) [5]. Some oat, wheat, rye, and triticale isolates from Poland also appeared to be Pat1 [11]. In McDonald et al. [25] study appeared, that the isolates of the Pat5 clade were avirulent to susceptible wheat cultivars.

The research reported in this paper is based on data collected over 2015 to 2020. Its aim was to provide more information on the natural occurrence, its spatial and temporal distribution of the complex of fungi of *Parastagonospora* spp./*Zymoseptoria tritici,* the common necrotrophic pathogens of wheat and triticale worldwide and especially in Poland.

Field Experiments

The studies were conducted in 8 experimental locations of Poland. These were: Bartążek: 20.482843 E 53.71086 N, Bonin: 16.2477 E 54.153613 N, Borowo: 16.790134 E 52.114888 N, Grodkowice: 20.27488 E 49.970209 N, Małyszyn: 15.174479 E 52.744631 N, Oleśnica Mała: 17.260902 E 50.847896 N, Smolice: 17.183084 E 51.691261 N and Ożańsk: 15.17448 E 52.74463 N) during the years 2015-2020. The experiments consisted, respectively, 10 winter wheat and 10 winter triticale varieties. The varieties varied in their response to *P. nodorum* and to *Z. tritici*. The seeds were planted to field plots of size 1 × 10 m in a randomised block design. Plants on plots were not chemically protected [26-28]. In the summer plants on the plots were assessed visually and diseased plant parts were collected. The collected diseased plant samples were analysed mycologically to determine by which pathogen these were affected.

Lesions on infected plant parts were inspected with a binocular microscope (25 ×). Mature pycnidia were transferred onto an agar solid medium with a glass needle. Pycnidiospores from cirrhi were spread over the surface of the agar medium. Conidia were measured with a use of digital microscope camera. To produce monospore cultures individual spores were isolated on solid media: V8 juice-PDA was used for *Parastagonospora* spp. [29] and YMDA was used to develop *Z. tritici* [30].

The following taxonomic criteria were applied for species identification of developed isolates: visual assessment of disease symptoms, morphology and dimension of conidia, morphology of colony on artificial solid media (in vitro). Dimensions of conidia for individual species were following: 25-45 × 3-4 µm for *P. avenae* f. sp. *triticea*, 15-32 × 2-4 µm for *P. nodorum* [1], and 35-98 × 1-3 µm for *Z. tritici* [28]. The morphology of colony of each isolate was also used as a taxonomic criterium.

The data sets obtained in experimental locations were also statistically analysed with selected meteorological factors such as: absolute maximum temperature (°C), average maximum temperature (°C), absolute minimum temperature (°C), average minimum temperature (°C), monthly average temperature (°C), minimum near-surface temperature (°C), monthly sum of rainfall (mm), maximum daily rainfall (mm), first day of maximum rainfall, number of days with snow cover, number of days with rainfall, and number of days with snowfall. The interpolation of data obtained in each of the experimental location was estimated by software program language using such models as: Scikit-learn, pandas, geopandas, numpy and matplotlib. The training data set was expanded by rotation matrix of two-dimensional geographical coordinates in Euclidean space using the following equation of Harris et al. [31-34].

Description and discussion of results

Occurrence of pathogens on wheat and triticale

It is to state that significant differences among the eight locations spread around the country to study the natural incidence frequency of the pathogens were found. The average incidence of *Z. tritici* was most frequently identified on the studied genotypes of winter wheat. The average number of isolations of *Z. tritici* from the infected plant parts was statistically different from ones of *P. nodorum* ($p < 0.001$) and *P. avenae* f. sp. *triticea* ($p<0.001$). The incidenc of *P. avenae* f. sp. *triticea* appeared to be 86 times less frequent than that of *Z. tritici*, while *P. nodorum* was isolated 10 times less often as compared to *Z. tritici*. It was found that the incidence of *P. avenae* f. sp. *triticea* on winter wheat was 8 times less frequent than that of *P. nodorum.*

The most frequently isolated pathogen from winter triticale was *P. nodorum*. The difference between the average number of *P. nodorum* isolations from winter triticale in experimental plots over the study period of 2015-2020 and the average number of isolations of *P. avenae* f. sp. *triticea* and *Z. tritici* was statistically significant. Nevertheless, the difference in the average occurrence of *P. avenae* f. sp. *triticea* and *Z. tritici* was not statistically significant [35]. The mean number of isolations of *P. avenae* f. sp. *triticea* was 6.8 and the average number of isolations of *Z. tritici* was 7.7. According to previous studies, *P. nodorum* and *P. avenae* f. sp. *triticea* were considered as less host preferring pathogens, while the *Z. tritici* host preference to wheat was more distinct [1,13,36-38]. In the research conducted by Arseniuk et al. [1,39], Tian et al., and Sapkota et al., wheat was determined as the primary host for *Z. tritici*, while the occurrence of *Z. tritici* on triticale was not observed at all or it was observed only very rarely [1,6,35,40].

Lesions with mature pycnidia of *P*. *nodorum* on glumes of winter wheat and winter triticale were observed very rarely, i.e., in 53 cases on winter wheat and in 28 cases on winter triticale. Surprisingly, in 12 cases, *Z. tritici* symptoms were identified on winter wheat heads (cvs. Fidelius, Bogatka, Ostroga, Muszelka), while these were observed only one time on winter triticale cv Cyrkon. The latter phenomenon is not common, although it was already reported by Jones and Cooke [37]. There were also symptoms of *P. avenae* f. sp. *triticea* on heads of triticale cultivars Baltiko and Atletico (*n*=5 isolations). The rare incidence of *P. nodorum* on glumes could be attributed to breeding for resistance [27] and/or climatic changes [6]. In the studies by Arseniuk et al. [38], necrotrophic effector genes were identified in populations of breeding lines and cultivars; 57% of triticale lines and 30% of winter wheat cultivars were susceptible to the *SnTox3* necrotrophic effector. The other effectors, namely *SnTox1*, *SnTox5*, and *SnToxA* had a negligible effect on the susceptibility of lines at seedling and adult plant growth stages. In the present study, the average isolation number of *P. nodorum* from disease plant parts of winter triticale plants amounted to 25 times, while on winter wheat it amounted to 16 times only.

It was found that *Z. tritici* occurs on wheat glumes what is surprising although in other studies employing more sensitive monitoring methods demonstrated that the pathogen was detected even without clearly visible lesions on spikes [13]. In studies of Tian et al. [13] the antigen amount of *Z. tritici* was measured using BA-ELISA test, which revealed that there was a greater quantity of antigen in F-1 leaves than in the flag ones. Minimal amounts of antigen were detected in glumes, and none in grains, what is in accordance with data of Shaw et. al. [26] employing real-time PCR method on a large number of samples of *M. graminicola.* DNA was detected in grain samples of wheat. However, the formation of mature pycnidia of *Z. tritici* on spikes under natural conditions was never observed. Nevertheless, it is worth to note that the in present research this phenomenon manifests on very susceptible wheat varieties such as Fidelius, Bogatka, Ostroga, Muszelka. It is suspected that this is due to the fact that the disease progresses upwards on leaves very quickly, and reaches spikes when glumes are still green and quite soft, what speeds up to develop symptoms on glumes. Under favourable conditions *P. nodorum* can easily develop lesions on both, glumes and leaves. In research reported by Shaw et. al. [26], a strong correlation between *Phaeosphaeria nodorum* blotch abundance on wheat grains and leaves was found (r = 0.7). The pathogen was more detrimental to ears as compared to leaves. Pycnidiospores much easier are transferred with seed and no airborne spores would be necessary to begin the disease outbreak in consecutive years [26]. There is also always a high risk of grain quality deterioration in the following years.

Correlation between meteorological factors and occurrence of pathogens

Pearson correlation coefficients were calculated between meteorological factors and the occurrence of the studied pathogens. In total, 137 meteorological factors were considered but because of very low values of correlation coefficients their analysis is omitted. Using large numbers degrees of freedom it is statistically possible to prove significant of anything. Methods of statistics should not serves these purposes, despite the facts that some stubborn colleague researchers (28) try to use statistics to prove and to make convincing their, sometimes horrible, ideas, e.g. that the snow cover and freezing temperatures stimulate development of *Parastagonospora*/*Septoria tritici* blotches. However, I personally disagree with such conclusions as the above.

Conclusion

Climate changes are known to occur depending upon regions and seasons and affect natural incidences of pets and pathogens, and agricultural production as well. All these factors affect agricultural production and this way also food security and safety, since the yields are reduced in quantity and poorer in quality. To deterioration of yields contribute not only climate changes but also changes in populations of pests and pathogens stimulated by climatic conditions. It is not a mystery, that actual yields are being affected to a large extent by climate-dependent pathogens, to which belongs the complex of necrotrophic complex of fungi *Parastagonospora* spp./*Zymoseptoria tritici*. The present research aimed to statistically prove the impact of climatic factors on the on the natural incidence of the pathogens affecting green plant parts of winter wheat and winter triticale in Poland, however, the plant–pathogen–climate interactions were not proven statistically. The bunch of correlation coefficients, sometimes positive, sometimes negative was very low, thus making inferences very risky. It is generally known that the studied pathogens flourish under humid conditions and moderate temperatures. *Zymoseptoria tritici* prefers climate of north-west Europe and *P*. *nodorum* strives well in continental, mid-eastern and Eastern Europe. Regarding affected crops it was proven that wheat under natural conditions is largely affected by *Z. tritici* and triticale by *P*. *nodorum*.

References

1. Arseniuk E, Fried PM, Winzeler H, Czembor HJ (1991) Comparison of resistance of triticale, wheat and spelt to septoria nodorum blotch at the seedling and adult plant stages. Euphytica 55: 43-48.
2. Arseniuk E, Góral T, Scharen AL (1998) Seasonal patterns of spore dispersal of phaeosphaeria spp and stagonospora spp. Plant Dis 82: 187-194.
3. Mirzwa-Mróz E, Tvaruzek L, Zamorski C, Nowicki B (2005) Research on the development of Mycosphaerella graminicola [Fuckel] schroeter teleomorph on wheat leaves from Poland and Czech Republic. Acta Agrobot 58: 59-65.
4. Pietravalle S, Shaw MW, Parker SR, Bosch FVD (2003) Modeling of relationships between weather and Septoria tritici epidemics on winter wheat: A critical approach. Phytopathol 93: 1329-1339.
5. Mahtour A, Jarroudi ElM, Delobbe L, Hoffmann L, Maraite H, et al. (2011) Site-specific septoria leaf blotch risk assessment in winter wheat using weather-radar rainfall estimates. Plant Dis 95: 384-393.
6. West JS, Townsend JA, Stevens M, Fitt BD (2012) Comparative biology of different plant pathogens to estimate effects of climate change on crop diseases in Europe. Eur J Plant Pathol 133: 315-331.
7. Fones H, Gurr S (2015) The impact of septoria tritici blotch disease on wheat: An eu perspective. Fungal Genet Biol 79: 3-7.
8. Fernandez MR, Stevenson CF, Hodge K, Dokken-Bouchard F, Pearse PG, et al. (2016) Assessing effects of climatic change, region and agronomic practices on leaf spotting of bread and durum wheat in the western Canadian Prairies, from 2001 to 2012. Agron J 108: 1180-1195.
9. Johnson T (1947) A form of leptosphaeria avenaria on wheat in Canada. Can J Res 25: 259-270.
10. Leath S, Scharen AL, Lund RE, Dietz-Holmes ME (1993) Factors associated with global occurrences of septorianodorum blotch and septoria tritici blotch of wheat. Plant Dis 77; 1266-1270.
11. Malkus A, Reszka E, Chang CJ, Arseniuk E, Chang PFL (2005) Sequence diversity of β-tubulin (tubA) gene in phaeosphaeria nodorum and P. avenaria. FEMS Microbiol Lett 249: 49-56.
12. Reszka E, Chung KR, Tekauz A, Malkus A, Arseniuk E (2005) Presence of β-glucosidase (bgl1) gene in phaeosphaeria nodorum and phaeosphaeria avenaria f. sp. triticea. Can J Bot 83: 1001-1014.
13. Tian S, Wolf GA, Weinert J (2005) Accurate assessment of wheat and triticale cultivar resistance to Septoria tritici and stagonospora nodorum infection by biotin/avidin ELISA. Plant Dis 89: 1229-1234.
14. Downie RC, Lin M, Corsi B, Ficke A, Lillemo M, et al. (2021) Septoria nodorum blotch of wheat: Disease management and resistance breeding in the face of shifting disease dynamics and a changing environment. Phytopathology.
15. Bhathal JS, Loughman R, Speijers J (2003) Yield reduction in wheat in relation to leaf disease from yellow (tan) spot and septoria nodorum blotch. Eur J Plant Pathol 109: 435-443.
16. Bearchell SJ, Fraaije BA, Shaw MW, Fitt BD (2005) Wheat archive links long-term fungal pathogen population dynamics to air pollution. Proc Natl Acad Sci 102: 5438-5442.
17. Lin M, Ficke A, Cockram J,Lillemo M (2020) Genetic structure of the norwegian parastagonospora nodorum population. Front. Microbiol 11: 1280.
18. Hekuran V, Belul G, Foto K, Halit S, Thanas R (2012) The relationship between diseases index of septoria leaf blotch, leaf rust and yield losses in bread wheat cultivar in Albania. J Environ Sci Eng 1: 957.
19. Witkowska K, Śmiałowski T, Witkowski E (2011) Dependence of the yield of winter wheat sows on the degree of infection by stagonospora nodorum and puccinia triticina under different field conditions. J Bull Plant Breeding and Accl 262: 47-57.
20. Torriani SF, Melichar JP, Mills C, Pain N, Sierotzki H, et al. (2015) Zymoseptoria tritici: A major threat to wheat production, integrated approaches to control. Fungal Genet Biol 79: 8-12.
21. Glazek M, Krzyzinska B, Maczynska A (2005) Occurrence of stagonospora nodorum glume blotch of wheat in the region of middle-southern Poland. Acta Agrobot 58: 23-28.
22. Arseniuk E, Gilon M (2014) Monitoring of pathogenicity changes in populations of necrotrophic pathogens of cereals (stagonospora spp, Septoria tritici). 48: 272-278.
23. Cowger C, Silva-Rojas HV (2006) Frequency of phaeosphaeria nodorum, the sexual stage of stagonospora nodorum, on winter wheat in North Carolina. Phytopathology 96: 860-866.
24. Solomon PS, Lowe RG, Tan KC, Waters OD, Oliver RP (2006) Stagonospora nodorum: Cause of stagonospora nodorum blotch of wheat. Mol Plant Pathol 7: 147-156.
25. McDonald MC, Razavi M, Friesen TL, Brunner PC, McDonald BA (2012) Phylogenetic and population genetic analyses of phaeosphaeria nodorum and its close relatives indicate cryptic species and an origin in the fertile crescent. Fungal Genet Biol 49: 882-895.
26. Shaw MW, Bearchell SJ, Fitt BD, Fraaije BA (2008) Long-term relationships between environment and abundance in wheat of phaeosphaeria nodorum and mycosphaerella graminicola. New Phytol 177: 229-238.
27. Crook AD, Friesen TL, Liu ZH, Ojiambo PS, Cowger C (2012) Novel necrotrophic effectors from stagonospora nodorum and corresponding host sensitivities in winter wheat germplasm in the southeastern United States. Phytopathology 102: 498-505.
28. Bartosiak SF, Arseniuk E, Szechyńska-Hebda M, Bartosiak

2021
Vol. 12 No. 5:180

E (2021) Monitoring of natural occurrence and severity of leaf and glume blotch diseases of winter wheat and winter triticale incited by necrotrophic fungi parastagonospora spp. and zymoseptoria tritici. Agronomy 11: 967.

29. Eyal Z, Scharen AL, Prescott JM, Van Ginkel M (1987) The septoria diseases of wheat: Concepts and methods of disease management CIMMYT: Mexico.

30. John E, Lopez-Ruiz F, Rybak K, Mousley CJ, Oliver RP, et al. (2016) Dissecting the role of histidine kinase and HOG1 mitogen-activated protein kinase signalling in stress tolerance and pathogenicity of Parastagonospora nodorum on wheat. Microbiology 162: 1023.

31. Saidi A, Eslahi MR, Safaie N (2012) Efficiency of septoria tritici sporulation on different culture media. Trakia J Sci 10: 15-18.

32. Pedregosa F, Varoquaux G, Gramfort A, Michel V, Thirion B, et al. (2011) Scikit-learn: Machine learning in Python. J Mach Learn Res 12: 2825-2830.

33. The Pandas Development Team (2020) Pandas-dev/pandas: Pandas; Zenodo: Geneva, Switzerland.

34. Harris CR, Millman KJ, Van der Walt SJ, Gommers R, et al. (2020) Array programming with numPy. Nature 585: 357-362.

35. Deisenroth MP, Faisal AA, Ong CS (2020) Mathematics for machine learning. Cambridge University Press.

36. Sapkota R, Knorr K, Jørgensen LN, O'Hanlon KA, Nicolaisen M (2015) Host genotype is an important determinant of the cereal phyllosphere mycobiome. New Phytol 207: 1134-1144.

37. Jones DG, Cooke BM (1969) The Epidemiology of Septoria tritici and S. nodorum: I. A tentative key for assessing septoria tritici infection on wheat heads. Trans Br Mycol Soc 53: 39-46.

38. Arseniuk E, Walczewski J, Ochodzki P (2019) Protein toxins of Parastagonospora nodorum and their relation to pathogenicity and resistance of triticale and wheat to leaf and glume blotch. Commun Agric Appl Biol Sc 286: 71-73.

39. Mehra LK, Cowger C, Gross K, Ojiambo PS (2016) Predicting pre-planting risk of stagonospora nodorum blotch in winter wheat using machine learning models. Front Plant Sci 7: 390.

40. Bartosiak E, Arseniuk E, Szechyńska-Hebda M, Bartosiak E (2021) Monitoring of natural occurrence and severity of leaf and glume blotch diseases of winter wheat and winter triticale incited by necrotrophic fungi *Parastagonospora spp*. and Zymoseptoria tritici. Agronomy 11: 967.